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ABSTRACT

An overview is provided of the current status of technical and vocational mathematics in the two-year college. Section I traces the development of technical math courses and discusses their function in the two-year college curriculum. Section II examines the use of applied math problems appropriate to particular vocational programs as an aid in motivating students; contrasts technical math courses with vocational math courses; advocates the coordination of math courses with other components of the technical or vocational program; and describes the basic topics to be covered in a technical math course to provide a good math background. The third section presents a profile of the technical-vocational math student and his/her educational background and needs, after which section IV looks at the extent to which calculators and computers are and should be used in technical math courses. Section V focuses on technical-vocational mathematics faculty, the reasons many do not wish to teach technical math, ways of getting faculty interested in teaching the courses, the importance of formal and informal meetings with members of the technical departments of the college, and the difficulty of updating and upgrading technical math instructors. Finally, section VI projects future developments, including a continuation of the growth in technical and vocational math courses. (HB)

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TECHNICAL MATHEMATICS IN TWO-YEAR COLLEGE PROGRAMS

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Sloan Foundation Conference

New Directions in Two-Year College Mathematics

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SUMMARY

Technical and vocational mathematics courses are service courses which cover the mathematics, and appropriate applications, needed in technical and vocational programs. The development of the mathematics is non-rigorous. The applications show where and how mathematics is used, but do not require a knowledge of a specific technical subject by either the student or the instructor. A primary reason for the establishment of these courses is that traditional mathematics programs do not meet the needs of the technical programs in material development, timing of topic coverage and applications. Motivation of students, who are often not well prepared academically, is a major reason for the emphasis on applications.

Technical mathematics courses should be coordinated with the technical courses of the program. The best way to accomplish this is through formal and informal meetings with technical faculty.

The calculator is used in all technical mathematics courses and is a great assist in teaching many topics. The computer is also used, although it is generally not integrated directly into the course as is the calculator.

Many mathematics faculty persons prefer not to teach technical mathematics because of the applications, and many do not prefer to teach vocational mathematics because of the mathematical level. This problem has no easy solution.

Technical and vocational mathematics courses will continue to grow due to the strong emphasis on technology in industry.

I. The Development of Technical Mathematics

Mathematics is the basic tool used by technicians of all fields to analyze and solve problems which arise in applied situations. This means that technicians require a knowledge of mathematics, and that technical programs should include appropriate mathematics courses.

There have been many college mathematics courses developed which have been directed specifically at students enrolled in various vocational and technical programs. These courses are now generally labeled as vocational, industrial or technical mathematics. The purpose of these courses is to provide the mathematics necessary in the curriculum, with a greater emphasis on identifying and using applied problems which are appropriate to the students' program. The mathematics topics covered, the level at which the courses are presented, and the emphasis given to the applications vary considerably with the type of program, the college, and the instructor.

Technical and vocational mathematics courses are primarily service courses. The emphasis should be to develop properly the mathematics which is needed and used in other program courses, including mathematics courses. The development of the material is done in a non-rigorous way. Applied problems are an integral part of such courses, and the applications should be directed at the students' curriculum to the greatest extent possible. However, the use of applications serves to show where and how mathematics is used and does not require prior knowledge of a specific technical subject by either the student or the instructor.

The American Mathematics Association of Two Year Colleges (AMATYC) has established a standing committee on technical mathematics. In the proposal (1) for establishing the AMATYC Technical Mathematics Committee the "newness of the technical mathematics movement" was noted. This refers to the rapidly growing number of courses at two year colleges and the general awareness today of such courses under the general heading of technical mathematics. However, it should be noted that some textbooks which are in use today are revised editions of texts which were used in courses especially designed for certain technical programs as early as the 1920's. Also, a number of textbooks intended for use by students in technical programs were developed during the 1950's and 1960's. Sessions dealing with technical mathematics were held at statewide (New York) faculty meetings in the 1950's.

There are many reasons which have led to the development of technical mathematics. The proposal for the establishment of the AMATYC Technical Mathematics Committee states that "traditional mathematics programs are not meeting the needs of these technical programs and most institutions are finding the need to offer two different tracks of mathematics education." The traditional programs usually do not have the less formal material development, timing (related to the needs of the other technical program courses) of topic coverage, and application coverage which is appropriate for the technical students and programs. About ten years ago I made a study of over 100 two-year college catalogs and found that about 75% of the colleges offered mathematics courses specifically designed for technical students,

while about 10% had their technical students take the traditional types of courses with the students of other programs. The remaining 15% did not offer these types of technical programs. Although my survey has not been updated, the Conference Board of Mathematical Sciences survey (2) in 1980-81 reports that "many two-year colleges ... have greatly expanded their scope to include a host of vocational programs." One of the highlights of the report was that "In two-year colleges occupational/technical program enrollments now lead college transfer enrollments."

II. Applications and Technical Mathematics Courses

Helping to motivate students enrolled in technical and vocational programs is one of the major reasons for the emphasis on applications. When the mathematics is related to their curriculum through the use of appropriate applied problems (rather than the approach where applications are used infrequently), students better understand the need for the mathematics that they are expected to learn.

Many mathematics educators have observed that the use of applications does help motivate students in the learning of mathematics. William A. Granville in the preface to his 1911 calculus book (3) noted that "simple practical problems have been added throughout; problems that illustrate the theory and at the same time are of interest to the student". Clarence E. Tuites in the preface to his 1946 technical mathematics text (4) says "representative problems from the various technical fields have been selected so that a student with a particular interest in one

of these fields may be given an assignment of practice problems illustrative of the use of mathematics in his chosen field". The CLPMP Panel (5) in 1982, in giving their recommendations for minimal mathematical competencies for college graduates, stated that courses "should be designed to be appealing and significant to the student", and that "almost all undergraduate courses in mathematics should give attention to applications". A study (6) at Stanford University in 1983 reported that providing general motivation in the class was found to be an important point in making a class easy to follow. The report states that "usually the motivation has to do with the expected future use, with repeated applications, or with other factors of relevance to the students". Also from my own experience of over twenty years of teaching technical mathematics I can say that it has been many years since I heard the question "what is this good for?"

One point should be reemphasized. Although applications are an important part of a technical mathematics course, the primary content is still mathematics. Frequently it is the only mathematics course which a technical student will ever take in college, and it should provide a good mathematics **background**. The student may wish to take more mathematics at some time in the future, and most employers of technical program graduates want students to have had a good general **background** so that they may be more adaptable to a variety of possible job opportunities. Over a period of years in meetings of technical program advisory committees and in many personal conversations with people from industry, I have heard employers ask for certain specific skills and a good general background. Also, an informal study (7)

reported in the American Mathematical Monthly that employers of graduates from four year mathematics programs also prefer a good general background as well as specialized courses.

To some, the meaning of technical mathematics is more general than to others. In its more general meaning it includes nearly all mathematics courses which are directed at specific two-year career programs, as opposed to the courses which are intended for a general student audience or for students intending to transfer to four-year colleges. In its more restricted meaning it includes those courses which are directed primarily at engineering related technical programs such as electronics technology, mechanical technology, chemical technology and architectural technology. The courses intended for rather specific career programs, and which generally require a somewhat lesser level of mathematics, are often referred to as vocational, industrial or occupational mathematics. These would include courses for students in technologies such as automotive, construction, electricity, air-conditioning, machine, drafting, police science, agriculture, fire science, forestry, and welding. Courses for other career programs such as business technology, data processing and nursing are sometimes referred to as technical mathematics, although they are also commonly labeled business mathematics or some similar appropriate title. (In this paper the more restricted meanings of technical and vocational mathematics are intended.)

Vocational and industrial mathematics courses are often taught by the faculty of the vocational program, rather than by faculty of the mathematics department. Such courses often emphasize

applications to a much greater extent than mathematical content. Technical mathematics courses are generally taught by faculty of the mathematics department. Often these courses do not emphasize applications to the extent which would be appropriate for the students' programs. The mix of mathematics and applications which is appropriate for the course in any given program should vary with the needs of the program and the students who are enrolled. Designing the course properly requires a great deal of planning by the department as well as the instructor.

Technical and vocational mathematics courses should be coordinated with other program courses so that the mathematics topics are covered before they are encountered in these other courses. To do this requires consultation and coordination with the technical departments. Such consultation may reveal, for example, that electronics students need determinants and trigonometric curves at certain times, and that mechanical students do not need them, whereas the reverse may be true for conic section curves. Thus, courses must be developed which do not simply follow a traditional sequence of mathematical topics and which develop course content that is not simply a review of material which the student may have had previously.

The mathematical content of technical mathematics courses generally consists of algebra and trigonometry. Some technical programs such as electronics technology and mechanical technology often require some of the more advanced topics in algebra and trigonometry as well as some calculus. Since the courses should be designed to be coordinated with other technical program courses and are often trying to upgrade a student's skills, such

courses very often integrate coverage of topics in algebra and trigonometry. With the applications and topics from algebra, trigonometry and calculus, a great variety of course sequences is possible, and in fact is found in two-year college programs. Another feature of a well designed course is that it should proceed somewhat slower at the beginning so that students can succeed and realize that the material can be learned.

A technical mathematics course covers most of the basic topics in algebra and trigonometry, although some of the more advanced topics (e.g. radical equations, matrices, trigonometric equations) are frequently not covered. In the basic coverage, only a few topics such as the more advanced methods of factoring, or the sum and product of the roots of a quadratic equation, are generally not covered. Besides applications, graphing is used more extensively. It is covered whenever it is appropriate (e.g. when discussing linear equations, quadratic equations, trigonometric functions, equation solving, etc.)

III. The Technical-Vocational Mathematics Student

Students enrolled in technical and vocational programs are usually not as well prepared academically as students intending to major in such programs as mathematics, science or engineering. Some of these students have well founded career plans when they enter college, whereas many choose technical or vocational programs not long before (or after) entering. This latter group includes those who have chosen the program because it will lead to a career "where the jobs are" (e.g. electronics or computers),

even though they really had not planned on or are truly committed to such a career. Also, many of these students were not serious students in secondary school. Therefore, motivating this group of students in much of their academic work in college becomes a major undertaking.

The mathematical needs of the students in vocational and technical programs depend on the backgrounds of the students and the program in which they are enrolled. A great many students enter vocational programs with weak backgrounds, in terms of both their mathematical skills and their attitudes towards learning. Although vocational mathematics courses generally consist of topics from arithmetic, geometry, basic algebra and trigonometry, and appropriate applications, many students have difficulty in handling these topics. It is necessary to develop these topics in such a way that they are not handled as strictly review in nature. The applications which are used provide a means of introducing mathematical topics as well as motivating students by showing where and how the mathematics is relevant to their program. The instructor must work closely with the students in showing them that they can indeed learn and use mathematics.

Students in technical mathematics courses generally have taken more mathematics than vocational program students in secondary school. Their backgrounds generally include elementary algebra and geometry, and often intermediate algebra and some trigonometry. However, they often do not know the material well and are unaware of this. Again, applications can be used to introduce mathematical topics as well as to show the relevance of the mathematics being covered.

IV. The Calculator and the Computer

The calculator is now used extensively throughout technical mathematics courses. It is also used in vocational courses, although when arithmetic is the topic its use is often restricted. In most technical mathematics courses the students are expected to have a scientific calculator, and most students are able to use it with a minimum of guidance. The calculator is of great value in teaching trigonometry. My experience (and that of many others) shows that topics such as triangle solution and vectors are now learned with much more success than in pre-calculator days. Students now find that they can get the right answer, and therefore understand the methods. Previously, they frequently could not handle the slide rule, came up with the wrong answer, and thereby thought that they did not understand the methods involved. There is little doubt that the calculator is of great assistance to students in learning and understanding technical mathematics.

The computer is also used in many technical mathematics courses. The computer language which is used more than any other is BASIC. However, the use of the computer is not often integrated directly into the course in the same way as the calculator. Computer programming and specifically computer related mathematical topics are generally not included. (These conclusions are found in a summary of textbook reviews which I studied in 1983.) Instructors use the computer to solve certain types of problems, but generally the students who use it are

familiar with the computer through other courses. However, there is no doubt that the use of the computer is increasing rapidly.

V. Technical-Vocational Mathematics Faculty

It has been frequently noted that applications are an integral part of a technical or vocational mathematics course. However, some mathematics instructors are hesitant to include many types of applications when teaching these courses since they are not very familiar with them and the related technical and vocational areas. This can be a difficult obstacle to overcome, and is one of the more serious problems found in the teaching of these courses. The instructor must realize that the applications show where and how the mathematics can be used, but that he or she is not expected to be expert in all technical areas. In fact, this can give the instructor an excellent opportunity to involve the students. The instructor, in stating that he or she is not very familiar with a certain applied situation, will often find that the students are eager to show the knowledge which they have gained from other technical program courses.

Many mathematics faculty persons do not prefer to teach technical mathematics because of the applications, and many do not prefer to teach vocational mathematics because they feel that the mathematical level of such courses is lower than they enjoy teaching. Getting these faculty members interested in teaching these courses is difficult. Involvement with the computer and seeing its applications has led some to find that such courses can actually be quite exciting. Becoming well acquainted with

faculty in the technical areas, sitting in on an occasional technical course class or laboratory session, taking technical courses in retraining programs or on sabbatical leave also shows some that these can be interesting courses. However, unless there is motivation on the part of these instructors, they tend to keep their reservations about teaching these courses.

When developing and updating technical and vocational mathematics courses, it is necessary to be aware of the needs of the programs being serviced. Attending sessions at conferences which are devoted to technical and vocational mathematics and being aware of the textbooks which are available can assist in this. However, one of the very best ways is to have meetings, formal and informal, with the members of the technical departments of the college. This provides the input and communication necessary to develop very useful technical and vocational mathematics courses. It also gives an excellent opportunity to interest mathematics faculty in technical programs. Another obvious benefit is that it can lead to a much better working relationship between departments.

The statements and conclusions just made regarding the preferences of technical mathematics instructors and the need for close consultation with technical departments are made after years of personal observations and numerous conferences and informal contacts with faculty in mathematics and technical departments. However, they are strongly reinforced by a study by R. M. Davis in 1980 (8) of service courses at two-year colleges. Davis states that "mathematics faculty have limited interest in teaching occupational-technical mathematics courses", and that

the "level of interface (between departments) is a key to successful occupational-technical programs".

The updating and upgrading of faculty is a general problem. Some take courses during summers and evenings; a few manage to get sabbatical leaves for professional development; some attend special workshops or conferences. Among the problems are scheduling of classes to allow time to take courses, difficulty in obtaining sabbatical leaves and financial reimbursement, and conflicting personal plans. Technical mathematics faculty probably need updating in two principal areas. One is computers, although the problem here appears to be dissipating rather quickly. The trend to use computers is very strong, and most instructors are now familiar with them. The other is, again, in the area of applications. The reluctance of instructors to use and assign applied problems can often be overcome if they become knowledgeable in one or two areas. Then they generally are willing to use the applications in other areas, even if they are not very familiar with the specific types of applied problems.

VI. A Look Ahead

Looking ahead, it appears that technical and vocational mathematics courses, along with nearly all mathematics courses, will continue to grow in number and in acceptance. One of the major reasons for this is the extremely strong emphasis on high technology in industry today. Technical program graduates in the years to come will need even stronger academic backgrounds, and mathematics must be one of the major components.

(1) Proposal For Standing Committee of AMATYC, Technical Mathematics Committee (March 31, 1981)

(2) Conference Board of the Mathematical Sciences, Report of Survey Committee, Vol. VI, 1980-81

(3) W.A. Granville, Elements of the Differential and Integral Calculus (Revised Edition), Ginn & Co., 1911

(4) C.E. Tuites, Basic Mathematics for Technical Courses, Prentice-Hall, 1946

(5) CUPM Panel, Minimal Mathematical Competencies for College Graduates, American Mathematical Monthly, April 1982, pp. 266-272

(6) N. Hativa, What Makes Mathematics Lessons Easy to Follow, Understand, and Remember ?, Two-Year College Mathematics Journal, November 1983, pp. 398-406

(7) A.K. Stenney, Undergraduate Training for Industrial Careers, American Mathematical Monthly, August-September 1983, pp. 478-481

(8) R.M. Davis, The Development and Delivery of Mathematics Service Courses at Two Year Colleges, Ph. D. dissertation, U. of Maryland, 1980

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